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# APPROACHES TO THE DEVELOPMENT OF INTERJURISDICTIONAL WATER QUALITY OBJECTIVES

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## ABSTRACT

Three methods of deriving Water Quality Objectives between jurisdictions are identified and the pros and cons of each approach are discussed. To set the stage, various definitions of Water Quality Objectives have been presented together with the concept and philosophy underlying objectives. Some common terms used in the process of developing objectives are defined, the steps in the process identified, and three categories of water quality parameters relevant to the protection of aquatic life are identified.

## DEFINITION OF WATER QUALITY OBJECTIVES

Water Quality Objectives can be defined in various ways. Some examples follow:

1. "Water Quality Objectives are concentration levels prescribed for water or biota which if exceeded may constitute a potential risk to one or more uses of that water; objectives therefore describe, in part, the poorest quality of water which will not only provide for, but also protect designated uses of that water (International Red River Pollution Board, 1984).

2. "A numerical concentration limit or narrative statement, based on scientific criteria, relevant socio-economic and other factors, which has been negotiated to support and protect designated uses of water (International Red River Pollution Board, 1984).

3. "A criterion adopted to protect the most sensitive designated use at a specific location with an adequate degree of safety, taking local circumstances into account. (In a given water-body, each objective may be based on the protection of a different water use, depending on the water uses that are most sensitive to the characteristics of concern in that waterbody, Egar, 1980.)

4. "Water Quality Objectives are first and foremost a tool for effecting water quality management (Belliveau, 1982).

The above definitions have in common the concept of Water Quality Objectives as a water management tool designed to protect designated water uses at a specified location. In order to translate the concept into meaningful terms for the purpose of examining how Water Quality Objectives can be addressed at an interjurisdictional boundary, some basic principles that underlay objectives, should be examined and some common terms relating to the development of Water Quality Objectives defined.

## PHILOSOPHY OF AND GUIDING PRINCIPLES BEHIND OBJECTIVES

Water Quality Objectives are developed for the most sensitive downstream use, as if that use occurred at the boundary. In this way, each jurisdiction is responsible for water quality management within its own area of jurisdiction.

Objectives should be developed for any parameters that can reasonably be considered to constitute actual, as well as potential water quality problems for the location in question. Within reason, Water Quality Objectives should be set so as to be in harmony within the jurisdictions involved. Once established, Water Quality Objectives should be reviewed periodically and may be revised through mutual agreement, but never changed unilaterally.

## WATER QUALITY CRITERIA, GUIDELINES, OBJECTIVES AND STANDARDS

The above terms are commonly used in the process of deriving Water Quality Objectives and Standards. Following is the commonly accepted definition of each term and Figure 1 places these terms within the context of the process.

1. Water Quality Criteria

   Levels of constituents where there are lethal and chronic effects on living organisms.

2. Water Quality Guidelines

   Levels which should not have adverse effects on living organisms. Levels are based on criteria, literature review, field and laboratory work, etc., and introduce a safety factor to criteria.

3. Water Quality Objectives

   Negotiated water quality values based upon guidelines, criteria and socio-economic information designed to protect a specific water use at a specified site.

4. Water Quality Standards

   An objective that is recognized in enforceable environmental control laws of a level of government.

## DEVELOPMENT OF WATER QUALITY OBJECTIVES

The most important step in development of objectives is the designation of downstream water uses by representatives of the downstream jurisdiction. These uses should correspond to the principal categories found in water quality criteria and guideline information in order that any subsequent objectives be effective and soundly based. The principal categories of uses are: drinking water or public water supply, aquatic life, agriculture (livestock watering and/or irrigation), recreation (contact and/or non-contact) and industrial. Once a decision is made with regard to uses, seslection of the parameters (water quality variables) and sampling media (water, sediment or biota) relevant to the specific uses can begin.

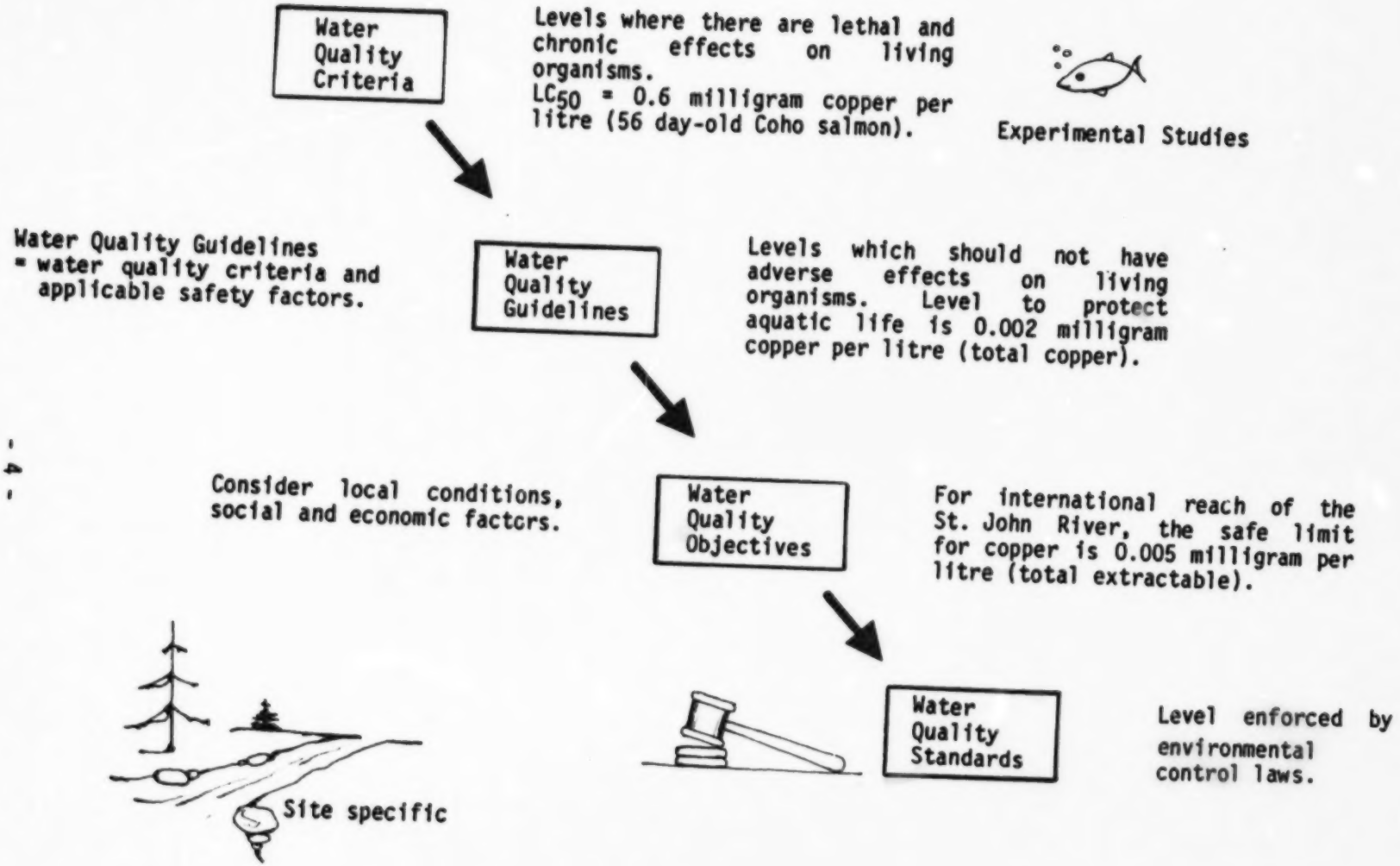

Water Quality Criteria
Levels where there are lethal and chronic effects on living organisms.
$LC_{50}$ = 0.6 milligram copper per litre (56 day-old Coho salmon).
Experimental Studies
Water Quality Guidelines = water quality criteria and applicable safety factors.
Water Quality Guidelines
Levels which should not have adverse effects on living organisms. Level to protect aquatic life is 0.002 milligram copper per litre (total copper).
Consider local conditions, social and economic factors.
Water Quality Objectives
For international reach of the St. John River, the safe limit for copper is 0.005 milligram per litre (total extractable).
Site specific
Water Quality Standards
Level enforced by environmental control laws.

**Figure 1: Relationship Between Water Quality Criteria, Guidelines, Objectives, and Standards**

As a result of this, a fairly large list of relevant parameters will usually be developed. It is not practical or possible to develop sound objectives for extensive lists of parameters; therefore, it is necessary to select the most significant parameters which will act as valid indicators of whether or not a specific use might be in danger of being impaired. Implicit within this step is an examination and evaluation of the existing data base, analyses of the data base in terms of trends and seasonal patterns, and an articulation of data and information gaps. Supplemental water quality and literature surveys may also be required.

At the same time, relevant water quality guidelines and criteria information should be compiled. In extreme situations, this may necessitate on-site criteria development if existing criteria are insufficient to address site-specific phenomenae.

Through a consultative process, the information on uses to be protected, significant indicator parameters, site-specific water quality data and information and related criteria and guidelines information, are put together in order to develop the site-specific water quality objective. Aside from the actual formulation of a number or limiting statement that constitutes the actual water quality objective, three other very important, concomitant considerations must also take place at this time. A monitoring strategy must be developed that will adequately service the particular objectives. A review process must be established in order that the objectives, once in place, can be continuously evaluated and upgraded when necessary. Thirdly, all decisions which led to the development of the specific objectives must be fully articulated in a rationale document.

The draft objectives, the monitoring strategy, and the draft rationale document are then tabled for consideration by negotiators. Decisions by negotiators, which lead to an adjustment or revision of the objectives must be reflected in subsequent drafts of the rationale documents.

The final step, prior to implementation, is ratification of the objectives by the senior levels of government of the two jurisdictions. Following ratification, implementation of the objectives involves adequate surveillance monitoring and ongoing review by some form of administrative committee or secretariat.

## WATER QUALITY PARAMETERS AND CRITERIA

From the foregoing discussion, it can be seen that the list of parameters or constituents to be included in Water Quality Objectives, established between two jurisdictions, is a function of the most sensitive designated downstream use to be protected; and that the validity of the numbers agreed to for an objective depends in part on the reliability of the existing data base.

By way of example, assume that the downstream jurisdiction identfies their most sensitive downstream use as aquatic life and associated recreation use. In the context of protection of aquatic life, water quality parameters can be generally divided into three categories. The three categories are:

1. **Parameters whose presence is acutely (short term) toxic to various forms of aquatic life.** These parameters may, in turn, be subdivided into synthetic organics and trace elements. Examples of acute toxic synthetics include PCBs, PPBs, Mirex, DDT, Dioxin or other synthetic substances regulated under the Canada Environmental Contaminants Act and the Canada Fisheries Act. Due to the toxic effects of these substances, objectives should be set at the detection level. Examples of acutely toxic trace elements are arsenic and selenuim. The Water Quality Objectives for acutely toxic organics should be set at the background level indicated in the existing data base. Trace elements are often not of anthropogenic origin; they may exist naturally in water bodies and in concentrations in excess of what the literature

indicates is acceptable. For this reason, it may not be reasonable to set the objective at the detection limit. The establishment of background levels is necessary and objectives should be related to these background levels.

2. **Paramaters whose presence above certain concentrations over time may be chronically toxic to various forms of aquatic life.** Examples are metals such as copper, mercury, lead and zinc. Here, the development of criteria and objectives are dependent on the existing water quality data base, and upon the science of ecotoxicology which is a new and evolving science, often depending on site-specific research. Thus, objectives based upon the above should be evaluated regularly and modified if the latest development in ecotoxicology or improvements in the data base so indicate.

3. **Parameters whose presence above certain levels or concentrations over time may impair the most sensitive use to certain degrees, but which are not acutely or chronically toxic to various forms of aquatic life.** Examples are major ions, color, taste and odor, nutrients and phenolic compounds. Again, development of criteria and objectives is dependent upon the quality of the existing data base.

## COMMON METHODOLOGIES FOR DEVELOPING WATER QUALITY OBJECTIVES

Three approaches which have been applied in Western Canada are identified and discussed for purposes of this paper. The approaches are **"Negotiated Single-Value", "Apportionment of Assimilative Capacity" (A+C/2)** and the **"Two-Level Approach".** Following is a brief evaluation of each approach.

### 1. Negotiated Single-Value

Essentially, the Negotiated Single-Value Approach entails establishment of one value or objective for each parameter under consideration.

It is, therefore, relatively simple and economic to implement and offers enough flexibility to enable parties to negotiate. However, since only one value is established for each parameter, there are a great deal of implicit assumptions contained in the objective, and the scientific integrity of the objective rests upon the integrity of the data base. The data should be collected, taking into account the various sampling media (physical, chemical and biological), the hydrologic and climatic characteristics of the fluvial system and the corresponding anthropogenic information. In-situ toxicity testing is often also highly desirable. Unfortunately, very little of these types of data usually exist.

Ultimately, a Single-Value Approach may be the most desirable method for developing Water Quality Objectives. However, until the data base is comprehensive enough and refined to a level which supports the scientific integrity of an objective; use of this method is difficult to defend except for acute toxics. Rather, a method should be used which maximizes the use of the existing water quality data base while at the same time recognizing the deficiencies in that data.

2. Apportionment of Assimilative Capacity (A+C/2)

The most common definition of "assimilative capacity" is usually stated in terms of the ability of receiving waters to absorb waste discharges without suffering deleterious ecological effects. In these terms, the assimilative capacity for a stream has often been perceived as some tangible, measurable amount which can be apportioned between two jurisdictions. The definition of assimilative capacity then becomes the numerical concentration of a constituent; chemical, biological or physical, that is equal to the difference between the maximum allowable concentration to protect the most sensitive designated uses on a stream, and the defined natural concentration.

In the (A+C/2), approach, "A" represents the natural (background) quality of the water at the border while, "C" is the maximum acceptable concentration in the water at the border which will support all designated downstream uses, as if these uses were located immediately downstream of the border. The range between A and C is divided equally between upstream and downstream jurisdictions, hence (A+C/2) to obtain the Water Quality Objective at this point. The division of this range on a 50/50 basis between jurisdictions is perceived to be an equitable apportionment of assimilative capacity. Assimilative capacity, and the subsequent Water Quality Objective which would be derived, becomes a design factor for upstream users and water managers.

The (A+C/2) concept can be very attractive from an administrative viewpoint in that it is seen as having potential for equitable water resource use between jurisdictions. However, in reality, assimilative capacity cannot be reduced to a conceptually simple value which represents degradation or non-degradation. The foremost advocates of the concept advocate its use in the study of aquatic ecosystems, but caution against its use as an administrative tool. Westman (1981) states

> . . . The history of implementation of the 1965 U.S. Water Quality Act, as documented in hearings before Congress in 1970 and 1971, showed vividly enough the bankruptcy of policies that assumed that sanitary engineers or other scientists could calculate accurately the levels of effluent discharge necessary to achieve water quality standards on major U.S. receiving waters (Cairns, J. 1981).

He also points out that the capacity to estimate accurately the stress which can be placed on a Water Quality Objective or standard does not exist.

The maximum acceptable concentration (C) assumes great importance in the (A+C/2) approach. By defining the upper limit of the assimilative capacity, it becomes the major factor in determining by how much the resultant Water Quality Objective will exceed the defined natural concentration (A), and hence how much pollution the upstream jurisdiction is allowed to contribute to the downstream jurisdiction. The higher the value that is assigned to the maximum acceptable, the greater is the potential jeopardy for the most sensitive use of the stream. Therefore, determination of the maximum acceptable concentration, with respect to the (A+C/2) concept has both environmental and economic significance. This dichotomy places a great deal of stress on setting a value which is the most acceptable compromise between the two concerns. The inherent difficulty in accurately quantifying or even defining what may be assimilative capacity, together with the potential difficulty in resolving a maximum acceptable level, makes the (A+C/2) methodology extremely difficult to implement in an equitable and scientifically defensible manner.

3. The Two-Level Approach

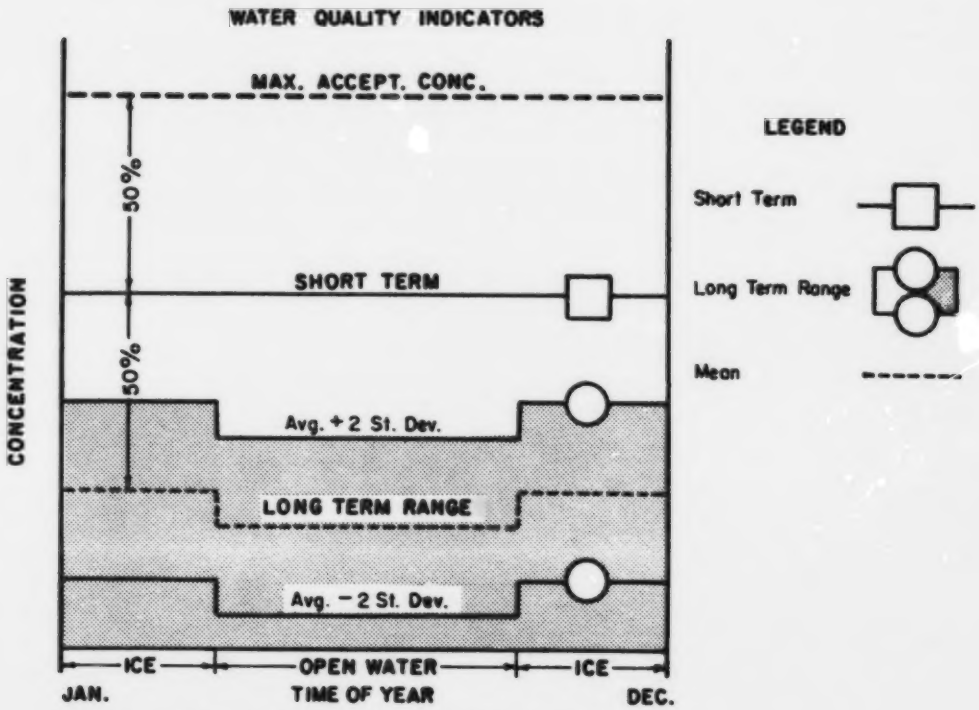
This method for developing Water Quality Objectives entails two levels which respectively identify short-term and long-term water quality requirements. The two levels identified for the Water Quality Objective are termed "alert level" and the "maximum acceptable level." The maximum acceptable level corresponds to an instantaneous objective, identifying short-term excursions on the basis of individual grab samples. The premise behind adopting the short-term level is that instantaneous excursions will indicate when a use is at potential risk. The "alert level" is structured in such a way that continued excursions will indicate a situation that requires evaluation as to whether an undesirable water quality situation exists. The long-term water quality level commits the participating jurisdictions to

respecting baseline quality. Together, the two levels constitute the water quality requirement for a specific parameter. Figure 2 illustrates this approach.

The alert level is defined as the range of concentration outside which a seasonal or annual mean will indicate a water quality situation which should be evaluated. The range is determined by plus and minus two standard deviations about the annual or seasonal means for the period of record. Seasons are identified on the basis of the presence or absence of ice cover and are tested for statistical differences in measured water quality.

The maximum acceptable concentration is defined as a concentration which, if not exceeded, ensures the protection of the most sensitive designated use. It is determined on the basis of existing data, and literature and through field and laboratory studies where applicable.

The Two-Level Approach is functional, sound, and a defensible method whereby Water Quality Objectives can be readily established. Less emphasis and time need to be taken in the setting of the maximum acceptable concentration. The Two-Level Approach is site-specific with regard to its alert values. Water quality is assessed against the long term objectives which, if exceeded, alerts the downstream jurisdiction to significant changes in baseline quality well in advance of any major infringement on its share of the resource, from whatever cause. The upstream jurisdiction is made aware of trends, well in advance of an excursion of the long term objective affording ample time to find the cause of an increasing concentration of a particular constituent.




NB. Average Level is based on Recorded Seasonal Data 1974 - 1982 Inclusive.

**Figure 2: The Two-Level Approach**

The method is scientifically defensible and considers natural or existing water quality characteristics as represented by data collected from a specific site over the period of record. This approach also accommodates the seasonal characteristics of water quality variables. The maximum acceptable level corresponds to an instantaneous level which can quickly be identified through analysis of monthly grab samples while over a period of time, any significant trends can be observed through examination of the alert level.

The two level method can be combined with a single negotiated value for acute toxics and can be used to work towards single negotiated values for all constituents over the long term as the data base and associated science evolve and improve.

## CONCLUSIONS

Of the three approaches examined, the Two-Level Approach is usually the most appropriate method of deriving interjurisdictional Water Quality Objectives. It retains maximum flexibility for each jurisdiction while protecting the long-term interest of the downstream jurisdiction, thus encouraging an equitable sharing of the resource. It is an effective method for situations where the existing data base is limited to selected analysis of the water column. As the data base becomes strengthened, the Single-Value Approach or a modification of the Two-Level Approach could be considered. The (A+C/2) approach is not considered appropriate due to difficulties in defining maximum acceptable concentrations and assimilative capacity and due to the relatively incomplete data base which usually exists.

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